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More prominent irregularities in velocity-curves have been observed by CAMPBELL¹ in ζ *Geminorum*, and by R. H. CURTISS in *W Sagittarii* (*l. c.*). The cause of these secondary curves is still an unsettled question. Various explanations have been offered, such as the presence of a third body; the rotation of the brighter component; a resisting medium; or the effects of tidal forces, which must necessarily be large in such close binaries. Dr. ALEXANDER W. ROBERTS has shown² that considerable deviations of the principal bodies from the spherical form, in the case where the size of the stars is distinctly comparable to the size of their orbits, would give rise to a secondary period in the velocity-curve equal to half the primary period. This is a very interesting and suggestive explanation, though probably not a complete one. In *W Sagittarii* the secondary period is without doubt half that of the primary, whereas in the case of ζ *Geminorum* a secondary period, equal to one third that of the primary, satisfies the observed curve better than one of half the primary period. In a complete explanation probably a number of factors must be taken into account, and in the different individual cases one or the other of these factors may become the predominant one, and thus produce differences in the period of the secondary or in other peculiarities of this class of variables. In the course of a few years, as studies of several other variables of this and related classes will become available, we may hope to be able to speak more authoritatively in regard to the characteristics that are common to all as well as the points of difference. In individual cases we may be able to pick out the predominant influences that are at work.

The Variable Star T Vulpeculæ.

The variable brightness of *T Vulpeculæ* was discovered by SAWYER in 1885. The binary character of the star was announced by FROST in 1904. Three series of spectrograms, in three successive years, were obtained and each series is satisfied by the same velocity-curve. There is thus no appreciable rotation of the line of apsides nor rapid change of any of the other elements. The solution of the orbit was made by the method of LEHMANN-FILHÉS. After several trials of various

¹ *Astrophysical Journal*, Vol. XIII, 90, 1901.

² *Monthly Notices R. A. S.*, Vol. LXVI, 329, 1906.

ellipses with different values of the elements, the velocity-curve computed with the elements given below was found to reproduce the observed velocity-curve well within the error of construction of the latter. A least-square solution was therefore considered entirely unnecessary. The following are the adopted elements:—

$$\begin{aligned} U &= 4^d.43578 \text{ (light-period),} \\ \mu &= 81^\circ.1583, \\ T &= 3^d.76 \text{ after light-maximum,} \\ \omega &= 111^\circ, \\ K &= 17.6^{\text{km}} \text{ (single amplitude),} \\ e &= 0.43, \\ V &= -1.3^{\text{km}} \text{ (velocity of system),} \\ a \sin i &= 969,180^{\text{km}}. \end{aligned}$$

In neither of these two stars could the variability be due to an eclipse, for in that case maximum and minimum brightness would occur near the points where the velocity equals the velocity of the system.

Perhaps the most important result of this investigation is the conclusive evidence of a much closer relationship between the light- and velocity-curves than has heretofore been believed to

Star.	Period.	Time Interval between Maximum Brightness and Greatest Negative Velocity.	Observer.	Reference.
		Days.		
ξ Geminorum ..	10.15	+ 0.2	W. W. CAMPBELL at L. O.	<i>Astrophysical Journal</i> , XIII, 90, 1901
η Aquilæ	7.18	+ 0.2	W. H. WRIGHT at L. O.	<i>Ibid.</i> , IX, 59, 1899
δ Cephei	5.37	— 0.2 \pm	A. BELOPOLSKY at Pul- kova.	<i>Ibid.</i> , I, 160, 1895
W Sagittarii ..	7.60	+ 0.1	R. H. CURTISS at L. O.	<i>Ibid.</i> , XXII, 274, 1905
T Vulpeculæ ..	4.44	— 0.3	S. ALBRECHT at L. O.	This article
Y Ophiuchi ...	17.12	+ 1.3 \pm	S. ALBRECHT at L. O.	This article
U Aquilæ	7.02	+ 0.5 \pm	S. ALBRECHT at L. O.	Not published
X Sagittarii ...	7.01	+ 0.3 \pm	J. H. MOORE at L. O.	Not published
S Sagittæ	8.38	0. \pm	R. H. CURTISS at L. O.	<i>L. O. Bulletin</i> 62
SU Cygni	3.85	+ 0.5 \pm	J. D. MADDRILL at L. O.	<i>Pub. A. S. P.</i> , XVIII, 252, 1906

exist. If the light is sent out equally in all directions from the variable star, the positions of light- and velocity-maxima and minima should bear no special relation to each other, for the brightness would be independent of the direction from which the star is observed, while the radial velocity at any instant is dependent upon the direction of the observer. For different stars

we should, therefore, expect the two curves to be shifted by different amounts relatively to each other around the period. For some stars greatest positive velocity would come at light-maximum, in others at light-minimum, and in most cases at other points along the light-curve. The table of the ten variables of this class for which both light- and velocity-curves are available shows that light-maximum and most rapid approach always occur together. Likewise, there is a time-correspondence between minimum brightness and greatest velocity of recession. We should therefore also expect that when irregularities¹ exist in both light- and velocity-curves, they will correspond to each other in position and perhaps also in shape. Of the ten stars in the above list only two have thus far shown marked irregularities in both light- and velocity-curves. They are *W Sagittarii*² and *Y Ophiuchi*; and for these the irregularities in the two curves correspond very closely.

This establishes the fact that in the variable stars of the δ Cephei type the light- and velocity-variations are very intimately connected; that both are due to the same causes; and that, if the velocity-variation is dependent upon the direction of the observer, so also must the observed light-variations be dependent upon the same factor.

At present the best theory for this class of variables seems to be that they are binaries, in which one of the component stars is considerably brighter than the other. The observed velocity-variation follows mainly as a direct consequence of the orbital motion of the brighter component. The light-variation seems to be caused in some way (other than eclipse) by the influence of the darker companion. The very close correspondence between the light- and velocity-curves in regard to period and shape, and the agreement of the times of occurrence of maximum brightness with greatest velocity of approach and minimum brightness with greatest velocity of recession, would indicate that the light-variation is not so much dependent upon the position of the brighter component of the system in its orbit as upon the direction from which the star is observed. This would ascribe less direct influence to the darker com-

¹ All the irregularities observed in the brightness- and velocity-curves of the stars contained in the table fall between light-maximum and light-minimum, except in the case of ζ Geminorum.

² *Astrophysical Journal*, Vol. XXII, 274, 1905.

panion in the matter of liberating an unusual amount of energy in a certain part of the orbit, most likely a small fraction of the period after periastron passage. Dr. CAMPBELL has called my attention to the fact that the *Algol* variables, which are binaries of even shorter average period than the δ *Cephei* variables, show no evidence of light-variation other than that caused by eclipse, and that the apparent failure of two *Algol* components to disturb each other should make us careful in ascribing the total observed effects in δ *Cephei* variables to the mutual disturbing powers of the components. Most of the eclipse variables have earlier-type spectra (*B*, *A*, and *F*) than the variables of Class IV. It is not impossible that in close binary pairs having the simpler types of spectra (*Algol* variables) the mutual disturbances are less effective in producing brightness-variations than in close pairs having older types of spectra (δ *Cephei* variables).

S. ALBRECHT.

ON THE DISTORTIONS OF PHOTOGRAPHIC FILMS ON GLASS.¹

Introduction.

In various lines of astronomical research depending upon photographic plates, discrepancies of a considerable magnitude occasionally appeared, which seemed attributable to no definite cause. On the star-photographs taken with the Crossley reflector these occasional discrepancies, which seemed to be more or less accidental, usually amounted to a few tenths of a second of arc, and very rarely to as much as a second of arc, which is equivalent to a linear distance of about 0.001 inch (0.02^{mm}). Even though discrepancies are the exception rather than the rule, and discrepancies of the magnitude referred to above are extremely rare, nevertheless they cause considerable annoyance when extreme accuracy is desired, for the error of measurement need not much exceed 0.001^{mm}. It seems highly desirable definitely to locate, if possible, the cause of the difficulty. In the case of the Crossley star-photographs it seemed for a time as though the cause must be sought for in the large mirror of the telescope. Another alternative was the study of the photographic film itself. Accordingly, in the winter of 1904,

¹ Thesis in partial fulfilment of the requirements for the degree of doctor of philosophy in the University of California. A more complete account is published in *L. O. Bulletin*, No. 118, and in the *Astrophysical Journal*, Vol. XXV, 349, 1907.